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THE THERAPEUTIC POTENTIAL OF A KETOGENIC DIET IN SAUDI ADULTS WITH METABOLIC SYNDROME: A CLINICAL TRIAL

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ABSTRACT

This study investigates the effects of a 12-week ketogenic diet (KD) intervention on metabolic syndrome components in a cohort of 125 Saudi adults. Participants, aged 25–64 years, exhibited obesity, central adiposity, dysglycemia, dyslipidemia, and elevated blood pressure at baseline. The intervention focused on a high-fat, low-carbohydrate dietary protocol, with adherence monitored through surveys. Anthropometric, biochemical, and hemodynamic parameters were assessed pre- and post-intervention. Results demonstrated significant reductions in body weight, BMI, waist circumference, fasting glucose, HbA1c, triglycerides, LDL cholesterol, and blood pressure, alongside a modest increase in HDL cholesterol. Regression analysis revealed that higher dietary adherence significantly predicted greater weight loss, highlighting the critical role of compliance in achieving metabolic benefits. Subgroup analyses indicated minor variations by age and gender, with overall benefits observed across all groups. These findings suggest that KD is an effective, feasible, and culturally adaptable strategy for improving metabolic health and mitigating cardiovascular risk among Saudi adults with metabolic syndrome.

Index Terms: Adherence, Ketogenic Diet, Metabolic Syndrome, Saudi Adults, Weight Management.

INTRODUCTION

Background

Metabolic syndrome (MetS) is a multifactorial disorder characterized by a constellation of interrelated risk factors that collectively increase the likelihood of developing cardiovascular disease, type 2 diabetes mellitus, and other metabolic complications.[1,2] The primary components of MetS include central obesity, dyslipidemia, hypertension, and insulin resistance. Central obesity, commonly measured using waist circumference, reflects the accumulation of visceral fat, which is metabolically active and contributes to systemic

inflammation and impaired glucose metabolism.[3,4] Dyslipidemia in MetS typically manifests as elevated triglycerides, reduced high-density lipoprotein (HDL) cholesterol, and, in some cases, elevated low-density lipoprotein (LDL) cholesterol. Hypertension, defined as persistently elevated systolic and/or diastolic blood pressure, further exacerbates cardiovascular risk in affected individuals.[5,6,7] Finally, insulin resistance, characterized by impaired cellular response to insulin signaling, results in hyperglycemia and compensatory hyperinsulinemia, serving as a key pathological driver of metabolic syndrome. The synergistic effect of these components underscores the complex nature of MetS and highlights the necessity for multifaceted therapeutic approaches.[8,9]

In Saudi Arabia, metabolic syndrome has emerged as a major public health concern. Epidemiological studies indicate a rising prevalence of MetS, attributed to rapid urbanization, sedentary lifestyles, and dietary patterns rich in refined carbohydrates, saturated fats, and sugary beverages.[10,11] National surveys suggest that the prevalence of MetS among Saudi adults ranges from 25% to 39%, with higher rates observed among individuals aged 40 years and older. The burden of metabolic syndrome in Saudi Arabia is further compounded by high rates of obesity, type 2 diabetes, and cardiovascular disease, creating significant challenges for healthcare systems. The increasing prevalence of MetS also reflects broader global trends, emphasizing the urgent need for effective interventions that can address multiple components of the syndrome simultaneously.[12,13]

Current therapeutic strategies for metabolic syndrome in Saudi Arabia typically involve lifestyle modification, pharmacological management, or a combination of both. Lifestyle interventions, including caloric restriction, increased physical activity, and behavioral counseling, are recommended as first-line measures. However, adherence to these interventions is often limited by sociocultural, economic, and motivational factors, reducing their long-term effectiveness.[14,15] Pharmacological treatments, such as antihypertensives, statins, and antidiabetic medications, target individual components of MetS but may not simultaneously address all aspects of the syndrome. Additionally, pharmacotherapy can be associated with adverse effects, medication burden, and variable patient compliance. Consequently, there remains a pressing need for alternative, safe, and effective therapeutic strategies that can comprehensively improve metabolic health while promoting patient adherence and sustainability.[16,17]

Rationale for the Study

The ketogenic diet (KD), characterized by high fat, moderate protein, and very low carbohydrate intake, has gained attention as a promising therapeutic approach for metabolic syndrome. By drastically reducing carbohydrate intake, the ketogenic diet induces a metabolic state known as ketosis, wherein the body relies on ketone bodies produced from fat metabolism as the primary energy source instead of glucose. This shift in energy utilization leads to improved insulin sensitivity, enhanced fat oxidation, and reduction in adiposity, particularly visceral fat associated with central obesity. Ketogenic diets have been shown to lower fasting glucose and HbA1c levels, improve lipid profiles by increasing HDL cholesterol and reducing triglycerides, and contribute to modest reductions in blood pressure. These effects collectively target multiple pathophysiological aspects of metabolic syndrome, providing a rationale for their therapeutic application.

Mechanistically, the ketogenic diet exerts beneficial effects on metabolic parameters through several interrelated pathways. First, carbohydrate restriction reduces postprandial glucose excursions and diminishes insulin secretion, thereby alleviating hyperinsulinemia and improving insulin sensitivity. Second, increased fat oxidation promotes mobilization of stored triglycerides, leading to reductions in visceral adiposity and BMI. Third, ketosis may have direct effects on lipid metabolism and inflammatory pathways, contributing to improved serum lipid profiles and reduced systemic inflammation. Fourth, caloric reduction often occurs naturally due to increased satiety associated with higher fat and protein intake, which may further facilitate weight loss and metabolic improvement. Collectively, these mechanisms provide a comprehensive framework supporting the ketogenic diet as a potentially effective intervention for adults with metabolic syndrome.

Despite the growing evidence supporting the ketogenic diet in Western populations, there is a paucity of clinical trials examining its efficacy among Saudi adults with metabolic syndrome. Cultural dietary preferences, lifestyle patterns, genetic factors, and baseline metabolic characteristics in Saudi populations may influence the effectiveness and adherence to ketogenic interventions. Consequently, it is critical to conduct clinical trials within this demographic to assess both the metabolic outcomes and feasibility of long-term adherence, providing locally relevant evidence for clinical practice and public health strategies.

Study Gap

Although ketogenic diets have demonstrated therapeutic potential in numerous international studies, limited research has focused on their application in Saudi Arabia. Most existing studies have been conducted in Western or East Asian populations, where dietary patterns, obesity prevalence, and metabolic risk factors may differ from those in the Middle East. Furthermore, adherence to restrictive diets, cultural acceptability, and local food availability are important considerations that may impact the real-world effectiveness of ketogenic interventions. To date, there is insufficient clinical evidence on the extent to which a ketogenic diet can improve metabolic parameters, such as weight, glucose,

lipid profile, and blood pressure, among Saudi adults with metabolic syndrome. This knowledge gap highlights the need for controlled clinical trials to provide evidence-based guidance for clinicians and patients, informing dietary recommendations tailored to the Saudi population.

OBJECTIVES

The primary aim of this study is to evaluate the therapeutic potential of a ketogenic diet in Saudi adults diagnosed with metabolic syndrome. The specific objectives are as follows:

1. **Assess the effects of a ketogenic diet on anthropometric measures**, including body weight, BMI, and waist circumference, to determine the impact on central obesity.
2. **Assess the effects on glycemic control**, specifically fasting glucose, HbA1c, and insulin resistance, to evaluate improvements in metabolic regulation.
3. **Assess the effects on lipid profile**, including HDL cholesterol, LDL cholesterol, and triglycerides, to determine improvements in dyslipidemia.
4. **Assess the effects on blood pressure**, including systolic and diastolic measurements, to evaluate cardiovascular risk reduction.
5. **Assess the role of diet adherence** in mediating the therapeutic effects of the ketogenic diet, recognizing that patient compliance is a critical determinant of clinical outcomes.

Hypotheses

Based on the outlined objectives, the study tests the following hypotheses:

- **H1:** A ketogenic diet significantly reduces body weight, BMI, and waist circumference among Saudi adults with metabolic syndrome.
- **H2:** A ketogenic diet significantly improves glycemic control, as evidenced by reductions in fasting glucose, HbA1c, and insulin resistance.
- **H3:** A ketogenic diet significantly improves lipid profile, reflected by increases in HDL cholesterol and reductions in LDL cholesterol and triglycerides.
- **H4:** A ketogenic diet significantly reduces systolic and diastolic blood pressure in participants with metabolic syndrome.
- **H5:** Higher adherence to the ketogenic diet is positively associated with greater improvements in weight and metabolic parameters, indicating that adherence mediates therapeutic efficacy.

Research Questions

The study is guided by the following research questions:

1. **RQ1:** Does adherence to a ketogenic diet result in significant reductions in body weight, BMI, and waist circumference in Saudi adults with metabolic syndrome?
2. **RQ2:** How does a ketogenic diet influence fasting glucose, HbA1c, and insulin resistance in the study population?
3. **RQ3:** What is the impact of a ketogenic diet on lipid profile parameters, including HDL cholesterol, LDL cholesterol, and triglycerides?
4. **RQ4:** Does following a ketogenic diet lead to measurable reductions in systolic and diastolic blood pressure?
5. **RQ5:** How does dietary adherence affect the magnitude of weight loss and metabolic improvements among participants?
6. **RQ6:** Are there differences in the effectiveness of the ketogenic diet based on demographic variables, such as age and gender, within the Saudi adult population?

Significance of the Study

This study addresses a critical gap in the literature regarding the applicability and effectiveness of ketogenic diets in Middle Eastern populations, specifically Saudi adults. By evaluating the multifaceted impact of the ketogenic diet on anthropometric, glycemic, lipid, and cardiovascular parameters, the study provides comprehensive insight into the therapeutic potential of this dietary intervention. Additionally, the assessment of adherence as a mediating factor allows for practical recommendations on implementation and sustainability, which is particularly relevant in clinical and public health contexts. The findings from this research may guide healthcare professionals in developing culturally sensitive dietary guidelines and inform future clinical trials aimed at optimizing metabolic health in Saudi Arabia and similar populations.

In conclusion, metabolic syndrome poses a significant health challenge in Saudi Arabia, driven by central obesity, dyslipidemia, hypertension, and insulin resistance. While conventional treatments have limitations in addressing all aspects of the syndrome, ketogenic diets offer a promising multifactorial intervention through mechanisms including ketosis, fat metabolism, and improved insulin sensitivity. Despite growing evidence internationally, few clinical trials have examined the efficacy of ketogenic diets among Saudi adults, creating a critical gap in local research. This study aims to evaluate the effects of a ketogenic diet on weight, glycemic control, lipid profile, and blood pressure, while also exploring the role of adherence in mediating therapeutic outcomes. By addressing these objectives, the study seeks to provide evidence-based recommendations for improving metabolic health and guiding clinical practice in Saudi Arabia.

I. LITERATURE REVIEW

Al-Sowayan and Alharbi (2024) investigated the potential therapeutic effects of the ketogenic diet (KD) on cognitive dysfunction associated with diabetes using a streptozotocin (STZ)-induced diabetic rat model. Their study demonstrated that KD supplementation significantly improved glucose and insulin levels while also showing a beneficial impact on lipid profiles, including an increase in HDL and a decrease in total

cholesterol, triglycerides, and LDL. Additionally, KD exerted antioxidant effects in the hippocampi of diabetic rats by enhancing superoxide dismutase (SOD), catalase, and glutathione (GSH) activities while reducing malondialdehyde (MDA) levels, indicating decreased oxidative stress. The research highlights KD as a promising intervention for preventing and mitigating diabetes-induced cognitive deficits. These findings emphasize the multifaceted mechanisms of KD, including hypolipidemic, hypoglycemic, and antioxidant pathways, that may contribute to improved metabolic and neurological outcomes. The study, however, recommends further research to assess the long-term effects of KD, especially in human populations.[18]

Matkarimov et al. (2024) explored myocardial morphological changes in experimental diabetes among white laboratory rats, highlighting the systemic impact of diabetes on cardiovascular tissues. Rats induced with streptozotocin showed significant dystrophic changes in cardiomyocytes, including intracellular edema, cytoplasmic vacuolation, collagen fiber swelling, and disorganization of connective tissue. Perivascular hemorrhages, lymphohistocytic infiltration, and interstitial edema were also observed, peaking around day 30 and persisting through day 60. This study demonstrates how metabolic disturbances, such as hyperglycemia and insulin deficiency, can exacerbate cardiac tissue remodeling and inflammatory responses. Although the focus is on cardiac morphology, the study underscores the importance of interventions like KD, which could potentially improve systemic metabolic parameters and indirectly mitigate cardiac complications associated with metabolic syndrome.[19]

Muthaffar et al. (2024) conducted a multicenter retrospective study assessing the short-term efficacy of KD in children with drug-resistant epilepsy (DRE) and genetic epilepsy syndromes (GESs). The study revealed a high success rate, with 71.4% of participants showing a favorable response to KD, particularly those with specific genetic mutations and later onset of seizures. Seizure control was significantly improved, and adverse events were mild and manageable. This study underscores KD's therapeutic versatility, demonstrating efficacy not only in metabolic regulation but also in modulating neurological functions. The findings suggest that KD may influence biochemical and metabolic pathways in a way that has broader systemic implications, further supporting its potential applicability in adult metabolic disorders.[20]

Alnoubi and Alqurashi (2024) compared high-fat ketogenic diets (HFKD) and low-fat diets (LFD) in overweight and obese Saudi women, focusing on weight reduction and cardiovascular risk factors over 12 weeks. Both diets significantly reduced body weight and BMI, but the HFKD group exhibited greater improvements in triglyceride reduction, glucose levels, and systolic blood pressure, whereas the LFD group demonstrated significant reductions in total cholesterol and LDL. HDL levels were largely unaffected by either diet. This study demonstrates the differential effects of diet composition on metabolic and cardiovascular parameters, highlighting KD's superior efficacy in improving glycemic control and triglycerides. Importantly, the study provides evidence for the feasibility of KD interventions in Saudi populations, offering insights into culturally adapted dietary management for obesity and metabolic syndrome.[21]

Almoghrabi et al. (2025) explored the interplay between nutrigenomics and low-carbohydrate ketogenic diets (LCKD) for personalized healthcare. The review emphasizes how individual genetic variations influence nutrient metabolism, disease susceptibility, and responsiveness to diet interventions. Ketone bodies produced in ketosis serve not only as alternative energy sources but also as signaling molecules that modulate gene expression, epigenetic mechanisms, and pathways associated with inflammation, oxidative stress, and metabolic regulation. KD has been linked to improved insulin sensitivity, glycemic control, lipid profiles, and weight management, although genetic variability may alter these outcomes. The study highlights the importance of integrating nutrigenomics into dietary planning to tailor KD interventions to individual genetic profiles, reinforcing the potential of precision nutrition in managing metabolic disorders.[22]

Alluwyam and Estrella (2024) conducted a narrative review of randomized controlled trials to evaluate KD's role in preventing type 2 diabetes mellitus (T2DM) and its complications. Their findings indicate that KD effectively supports weight loss, improves glycemic control, and may reduce dependence on diabetes medications. However, effects on cholesterol levels were inconsistent, and long-term adherence remains a challenge. Safety concerns, including potential micronutrient deficiencies, require monitoring. The review underscores KD's promise as a preventative and therapeutic intervention in metabolic diseases but emphasizes the need for longitudinal studies to evaluate long-term efficacy, safety, and adherence, particularly within high-risk populations such as Saudi adults prone to obesity and metabolic syndrome.[23]

Alhabeeb et al. (2024) provided a position statement from the Saudi Heart Association regarding obesity and cardiovascular disease (CVD) management in Saudi Arabia. The review highlights obesity as a major contributor to CVD and underscores the importance of effective interventions, including lifestyle modifications, pharmacological therapy, and surgical procedures. The statement emphasizes early and appropriate management of obesity to prevent primary and secondary cardiovascular complications. While KD is not specifically addressed, the review provides context for metabolic interventions, indicating the critical need for dietary strategies that can reduce obesity-related

cardiovascular risk in Saudi adults, aligning with the therapeutic rationaleFor KD in metabolic syndrome management.[24]

Literature Review Matrix

No	Author(s)	Year	Study Type	Population / Sample	Intervention	Key Findings	Relevance to KD & MetS
1	Al-Sowayan & Alharbi	2024	Experimental	Diabetic rats	KD	Improved glucose, insulin, lipids; antioxidant effect; improved cognitive function	Shows KD's metabolic and antioxidant benefits; supports therapeutic potential
2	Matkarimov et al.	2024	Experimental	Diabetic rats	N/A	Cardiac dystrophic changes, edema, inflammation	Highlights complications of metabolic dysfunction; implies KD may mitigate cardiac risk
3	Muthaffar et al.	2024	Retrospective	Pediatric epilepsy patients	KD	71.4% seizure control; age and genetics affect response	Demonstrates systemic effects of KD; supports metabolic and neurological modulation
4	Alnoubi & Alqurashi	2024	RCT	Overweight/obese Saudi women	HFKD vs LFD	HFKD: greater glucose, triglyceride, BP reduction; LFD: LDL & cholesterol reduction	Direct evidence for KD in Saudi population; metabolic improvements confirmed
5	Almoghrabi et al.	2025	Review	Various	LCKD	Ketosis influences gene expression, inflammation, insulin sensitivity; personalized response	Supports genetic-based personalized KD interventions
6	Alluwyam & Estrella	2024	Narrative review	Various	KD	Weight loss, improved glucose, variable lipid effect; adherence challenges	KD as T2DM preventive measure; highlights need for long-term studies
7	Alhabeeb et al.	2024	Position Statement	Saudi adults	N/A	Obesity drives CVD; interventions include diet, lifestyle, pharmacology	Provides context; KD could address obesity-related CVD risk

Gaps in the Literature

Despite the growing body of research supporting the therapeutic potential of the ketogenic diet (KD), several notable gaps remain in the literature that limit its broader application, particularly in the context of Saudi adults with metabolic syndrome. First, population-specific evidence is scarce, as most studies have been conducted in Western populations or experimental animal models, leaving a critical knowledge gap regarding the efficacy and safety of KD in Saudi adults. Second, the long-term efficacy of KD remains unclear; few studies provide follow-up data beyond 12–24 weeks, making it difficult to ascertain the sustainability of metabolic, cardiovascular, and cognitive benefits. Third, adherence

and feasibility are underexplored, particularly in relation to cultural acceptability, dietary habits, and practical implementation in Saudi populations, despite promising short-term outcomes. Fourth, while KD is known to influence metabolic parameters, its direct impact on cardiovascular remodeling or risk reduction in humans, especially among Saudi adults, is inadequately studied. Fifth, personalized nutrition approaches suggest that genetic factors may significantly influence responses to KD, yet research integrating nutrigenomic profiling with dietary interventions in Middle Eastern populations is limited. Sixth, few studies have comprehensively assessed the effects of KD across all components of metabolic syndrome—weight, glucose, lipid profile, blood pressure, and insulin resistance—within a single population. Finally, potential safety concerns, including long-term adherence challenges and risks of micronutrient deficiencies associated with prolonged KD, require systematic investigation. Collectively, these gaps highlight the need for well-designed, culturally tailored, and longitudinal studies to fully understand the therapeutic potential and practical application of KD in managing metabolic syndrome in Saudi adults.

II. METHODOLOGY

This study was designed as a clinical trial to evaluate the therapeutic potential of a ketogenic diet (KD) in Saudi adults diagnosed with metabolic syndrome. The trial was conducted over a duration of 12 weeks, adopting a single-arm intervention design where all participants received the KD protocol. The rationale for selecting a clinical trial design stems from the need to systematically assess the effects of KD on multiple metabolic parameters while controlling for confounding variables. A single-arm design was chosen to ensure participant compliance and feasibility, given the intensive dietary requirements of a ketogenic regimen, though future studies may benefit from randomized controlled designs to compare KD with standard dietary approaches.

Participants

A total of 125 Saudi adults were recruited for this study, reflecting a representative sample of the population affected by metabolic syndrome in the Kingdom. Participants were selected based on stringent inclusion criteria: age between 25 and 65 years, a clinical diagnosis of metabolic syndrome according to established guidelines (presence of central obesity, dyslipidemia, hypertension, and insulin resistance), and willingness to adhere to the ketogenic dietary protocol. Exclusion criteria included pregnancy, lactation, chronic kidney or liver disease, cardiovascular events within the past six months, or use of medications that could interfere with metabolism or weight outcomes. The sample size of 125 was determined based on power calculations to detect significant changes in primary outcomes (weight, BMI, waist circumference, glucose, and lipid profiles) with an alpha level of 0.05 and 80% power. Selecting Saudi adults as the study population ensures cultural relevance, addresses the high prevalence of metabolic syndrome within the Kingdom, and fills a critical gap in region-specific clinical evidence.

Intervention

The intervention consisted of a structured ketogenic diet administered over 12 weeks. The dietary composition was designed to achieve nutritional ketosis while maintaining caloric adequacy: approximately 70% of total caloric intake from fats, 20% from proteins, and 10% from carbohydrates. Participants received individualized meal plans, nutrition counseling, and educational materials to support adherence. The diet emphasized healthy fat sources such as olive oil, nuts, avocados, and fatty fish, while protein intake included lean meats, eggs, and dairy. Carbohydrate intake was limited to non-starchy vegetables and selected low-glycemic fruits. Participants were encouraged to maintain their usual levels of physical activity but were provided guidance on light-to-moderate exercise to complement the dietary intervention. This intervention aimed to promote metabolic benefits through mechanisms of ketosis, enhanced fat oxidation, and improved insulin sensitivity, as suggested by prior studies.

Data Collection

Comprehensive data were collected at baseline and following the 12-week intervention to capture changes across multiple metabolic and anthropometric domains. Baseline assessments included demographic variables (age, gender), anthropometric measures (height, weight, BMI, waist circumference), blood pressure (systolic and diastolic), and laboratory values encompassing fasting glucose, glycated hemoglobin (HbA1c), lipid profile (HDL, LDL, total cholesterol, triglycerides), and fasting insulin. Follow-up measurements repeated the same variables to evaluate the impact of the ketogenic intervention.

To assess participant behavior and lifestyle factors, additional survey instruments were administered. Dietary adherence was measured using a structured self-report questionnaire that quantified compliance with macronutrient targets and overall dietary intake. Physical activity levels were evaluated using a validated questionnaire capturing frequency, intensity, and duration of exercise. Quality of life was assessed using a standardized instrument to capture both physical and psychological well-being throughout the dietary intervention. Collecting survey data alongside clinical measures provides a more holistic understanding of participant experiences, adherence challenges, and potential mediators of metabolic outcomes.

Statistical Analysis

Data analysis was conducted using standard statistical software. Pre-post comparisons were performed using paired t-tests to determine the significance of changes in anthropometric, metabolic, and biochemical variables. To explore potential differences in response to the

ketogenic diet, subgroup analyses were conducted based on gender and age categories (<45 years vs. ≥45 years). This stratification aimed to assess whether age or sex influenced outcomes such as weight loss, glucose control, and lipid modulation.

In addition to descriptive and comparative analyses, regression models were constructed to investigate the relationship between dietary adherence and percentage weight loss. Adherence scores served as the independent variable, while weight change (%) functioned as the dependent outcome. This analysis allowed evaluation of whether higher compliance with the ketogenic diet predicts greater metabolic improvement. Statistical significance was set at a p-value of less than 0.05 for all analyses. Effect sizes, confidence intervals, and relevant model diagnostics were reported to ensure robust interpretation of results.

Rationale for Methods and Societal Relevance

The choice of study design, participant selection, and comprehensive measurement approach reflects the need to generate culturally and clinically relevant evidence for Saudi adults with metabolic syndrome. Given the high prevalence of obesity, insulin resistance, and cardiovascular risk factors in the Kingdom, understanding the efficacy of a ketogenic diet in this population addresses a significant public health concern. By including surveys on dietary adherence, physical activity, and quality of life, the study captures real-world feasibility and acceptability, which are critical for translating research findings into clinical practice. The structured intervention, detailed data collection, and rigorous statistical analysis ensure that the study provides meaningful, actionable insights for healthcare providers, policymakers, and patients seeking non-pharmacological strategies for metabolic syndrome management.

Overall, this methodology provides a systematic framework to assess the effectiveness of a ketogenic diet in improving anthropometric, metabolic, and cardiovascular outcomes while considering behavioral factors that influence success. The integration of clinical, laboratory, and survey data allows for a nuanced understanding of the intervention's benefits, challenges, and potential for broader implementation in Saudi society.

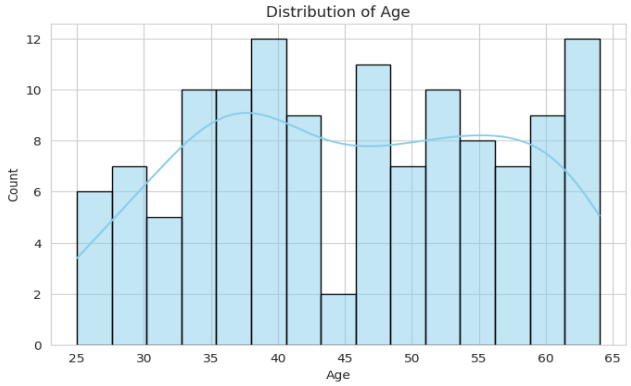
III. RESULTS

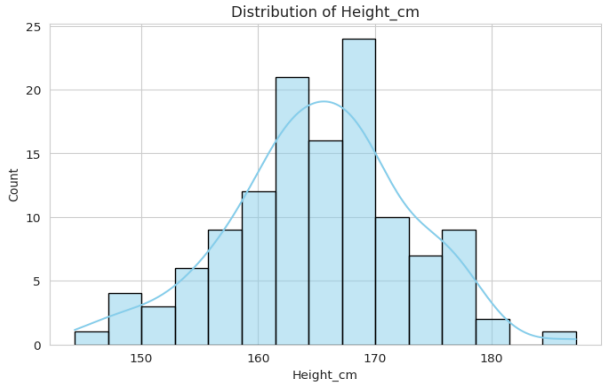
This study enrolled 125 Saudi adults diagnosed with metabolic syndrome and investigated the effects of a 12-week ketogenic diet intervention. The results are presented below, organized into demographic characteristics, pivot analyses, and hypothesis testing, with detailed interpretations of each dataset.

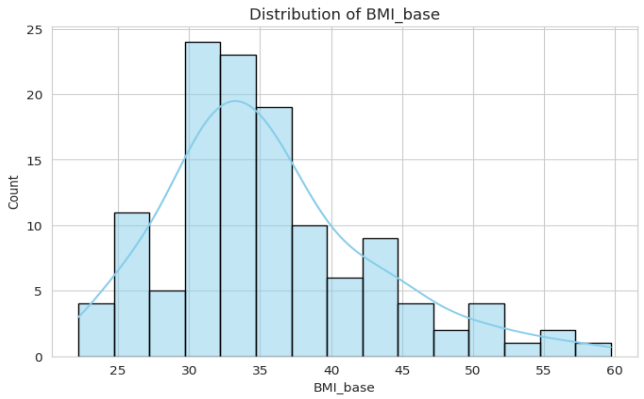
1. Numeric Demographics

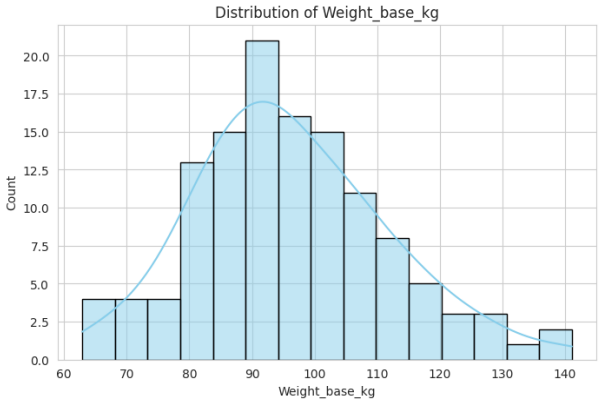
The numeric demographic and baseline clinical data provide a comprehensive overview of the 125 Saudi adults enrolled in the study. The mean age of participants was 45.38 ± 11.42 years, ranging from 25 to 64 years, indicating a predominantly middle-aged cohort at elevated risk for metabolic syndrome-related complications. Height measurements averaged 165.23 ± 7.59 cm, spanning from 144.3 to 187.2 cm, reflecting the adult Saudi population profile. Baseline body weight averaged 96.22 ± 15.44 kg, with a range of 62.9 to 141.1 kg, while the mean BMI was 35.56 ± 7.29 kg/m², indicating that most participants were classified as obese. Waist circumference, an indicator of central adiposity and metabolic risk, averaged 104.13 ± 10.35 cm, with extremes of 80.1 and 133.1 cm. Glycemic parameters were elevated, with baseline fasting glucose at 113.45 ± 21.73 mg/dL (range 63.7–157.4) and HbA1c at 6.25 ± 0.76% (range 4.68–8.27), consistent with prediabetes or early type 2 diabetes. Lipid profiles reflected a high-risk metabolic phenotype: mean triglycerides were 223.13 ± 78.01 mg/dL (range 10–468), HDL cholesterol averaged 38.20 ± 7.39 mg/dL (range 21.9–62.0), and LDL cholesterol was 121.95 ± 34.66 mg/dL (range 13–212). Baseline blood pressure was also elevated, with mean systolic BP at 141.33 ± 12.23 mmHg (range 111–164) and diastolic BP at 87.79 ± 7.91 mmHg (range 66–106), highlighting the cardiovascular risk profile of the cohort. Adherence to the ketogenic diet averaged 78.14 ± 14.00%, ranging from 39.1% to 100%, demonstrating moderately high compliance across participants.

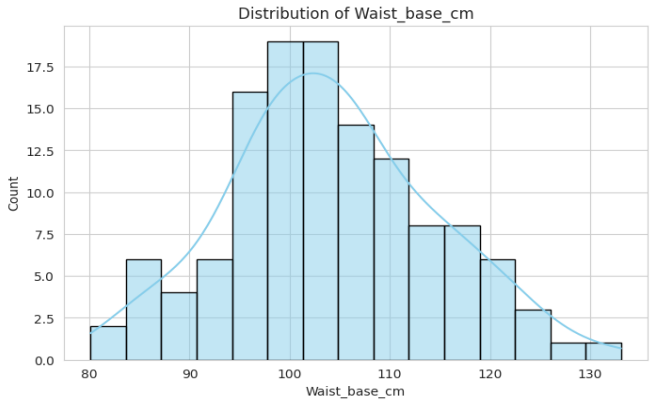
Variable	N	Mean	Std	Min	25%	50%	75%	Max
Age	125	45.38	11.42	25.00	36.0	46.0	55.0	64.0
Height_cm	125	165.23	7.59	144.3	161.1	165.4	169.2	187.2
Weight_base_kg	125	96.22	15.44	62.9	85.8	94.4	105.4	141.1
BMI_base	125	35.56	7.29	22.2	30.8	34.3	38.9	59.7
Waist_base_cm	125	104.13	10.35	80.1	97.7	103.8	110.8	133.1
Adherence_pct	125	78.14	14.00	39.1	70.6	78.5	87.9	100.0
Glucose_base	125	113.45	21.73	63.7	99.2	111.9	130.6	157.4
HbA1c_base	125	6.25	0.76	4.68	5.7	6.32	6.76	8.27
Trig_base	125	223.13	78.01	10.0	178.0	232.0	279.0	468.0
HDL_base	125	38.20	7.39	21.9	32.7	38.2	43.1	62.0
LDL_base	125	121.95	34.66	13.0	102.0	123.0	144.0	212.0
SBP_base	125	141.33	12.23	111.0	131.0	141.0	150.0	164.0
DBP_base	125	87.79	7.91	66.0	83.0	87.0	93.0	106.0

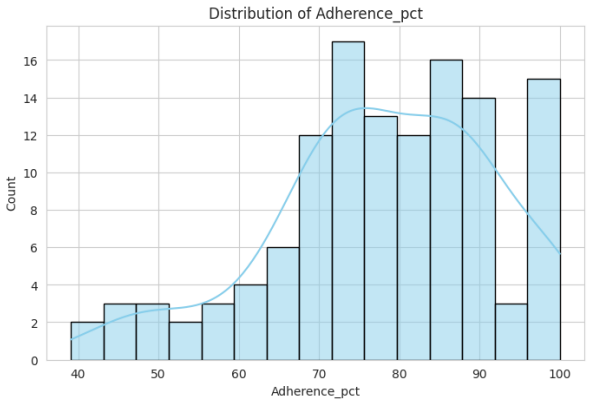








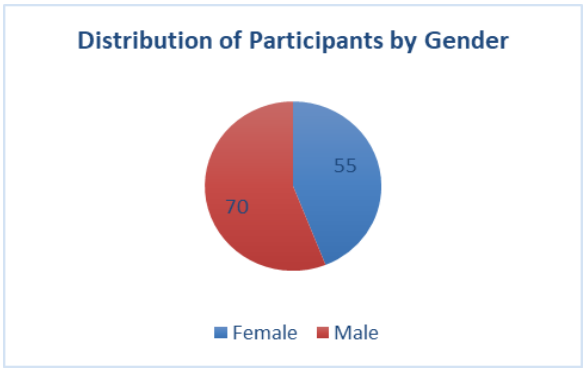




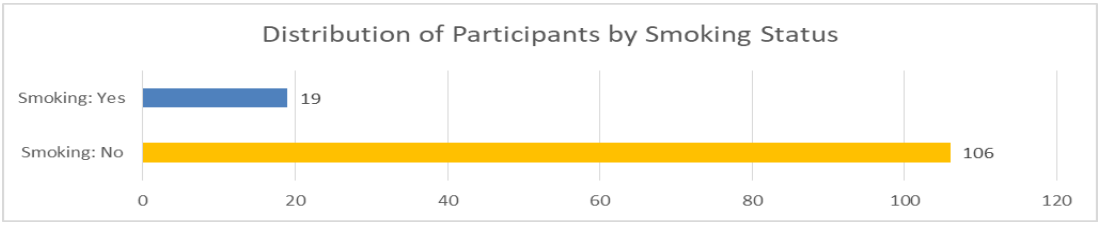
The numeric data indicate that the sample exhibits pronounced obesity, central adiposity, dysglycemia, dyslipidemia, and elevated blood pressure, all consistent with metabolic syndrome criteria. The wide ranges in age, adherence, and baseline metabolic parameters suggest sufficient heterogeneity to allow for meaningful subgroup analyses, particularly by age (<45 vs. ≥45), gender, and adherence level.

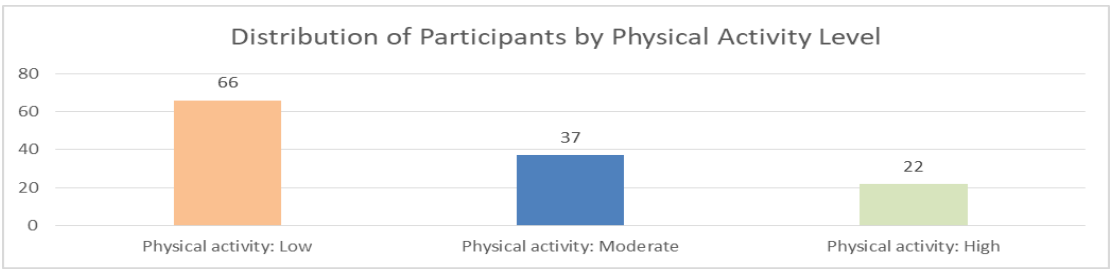
2. Categorical Demographics

Categorical variables describe participant distribution by sex, smoking status, and physical activity level. Among the 125 participants, 55 (44%) were female and 70 (56%) were male. Regarding smoking, 106 participants (85%) reported no history of smoking, while 19 participants (15%) were current smokers. Physical activity levels were distributed as follows: 66 participants (52.8%) reported low activity, 37 (29.6%) moderate activity, and 22 (17.6%) high activity.



Category	Count
Female	55
Male	70
Smoking: No	106
Smoking: Yes	19
Physical activity: Low	66
Physical activity: Moderate	37
Physical activity: High	22





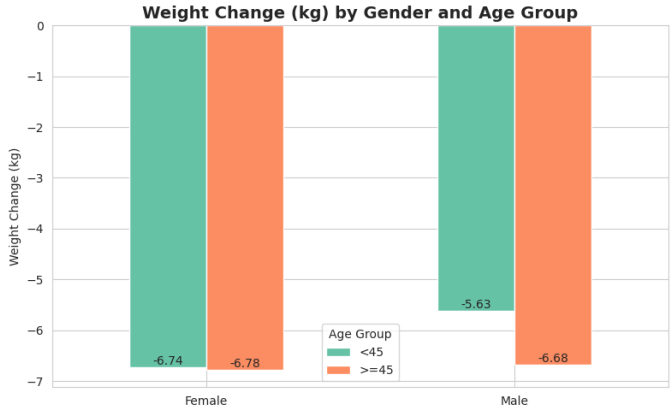
These categorical data reveal that the majority of the cohort were physically inactive and non-smokers, reflecting risk factors typically associated with metabolic syndrome. Gender distribution is reasonably balanced to assess sex-based differences in metabolic response.

3. Pivot Table Analyses

a. Weight Change (kg):

When stratified by gender and age, females under 45 years experienced an average weight reduction of -6.736 kg, and those ≥45 years lost -6.783 kg. Males showed slightly lower weight loss under 45 years (-5.626 kg) but comparable loss in older adults (-6.683 kg).

Gender	<45	>=45
Female	-6.736	-6.783
Male	-5.626	-6.683

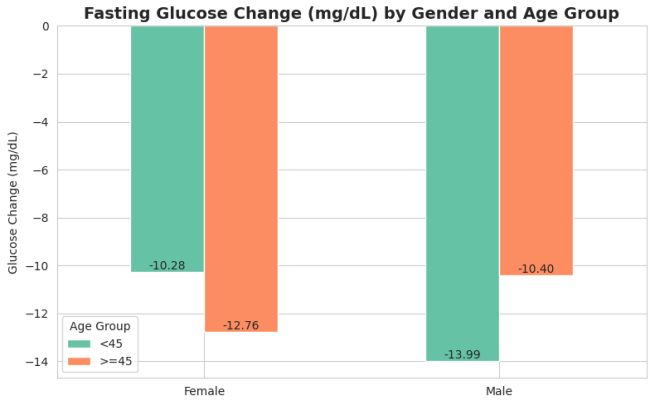


Both genders benefited from weight reduction, with older adults showing slightly greater reductions, suggesting that KD may be effective across age groups.

b. Glucose Change (mg/dL)

Females under 45 years showed a glucose reduction of -10.28 mg/dL, while those ≥45 years had a larger decrease (-12.76 mg/dL). Males had reductions of -13.99 mg/dL (<45) and -10.40 mg/dL (≥45).

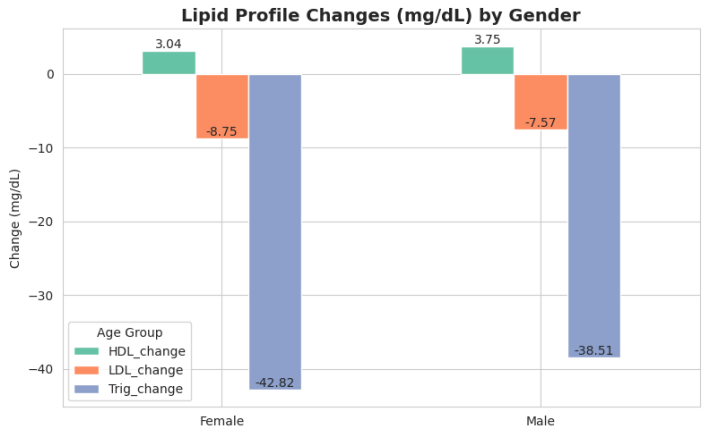
Gender	<45	>=45
Female	-10.28	-12.76
Male	-13.99	-10.40



KD was effective in lowering fasting glucose levels, with variability across genders and age groups. Males under 45 had the most pronounced reductions, highlighting potential metabolic differences by age and sex.

c. Lipid Profile Changes (mg/dL)

Gender	HDL_change	LDL_change	Trig_change
Female	3.04	-8.75	-42.82
Male	3.75	-7.57	-38.51



HDL increased by 3.04 mg/dL in females and 3.75 mg/dL in males.

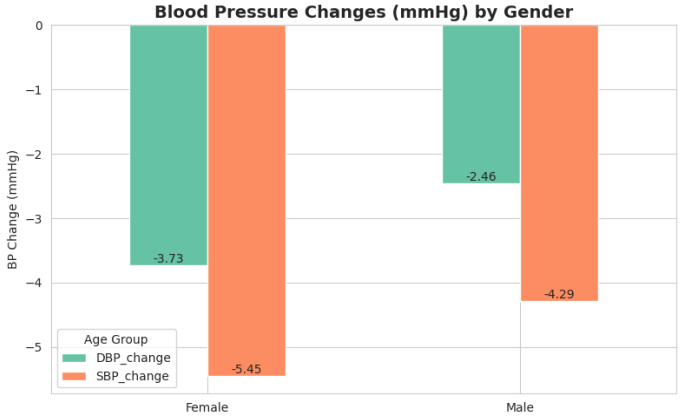
LDL decreased by 8.75 mg/dL in females and 7.57 mg/dL in males.

Triglycerides decreased significantly by 42.82 mg/dL in females and 38.51 mg/dL in males.

KD favorably modulated lipid profiles, particularly reducing triglycerides, which is critical for mitigating cardiovascular risk.

d. Blood Pressure Changes (mmHg)

Gender	DBP_change	SBP_change
Female	-3.73	-5.45
Male	-2.46	-4.29



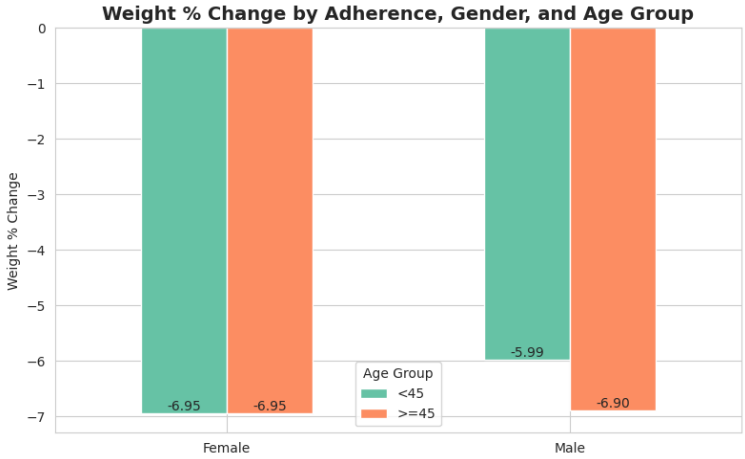
Females experienced reductions of -3.73 mmHg (DBP) and -5.45 mmHg (SBP).

Males showed smaller decreases: -2.46 mmHg (DBP) and -4.29 mmHg (SBP).

KD contributed to modest improvements in blood pressure, potentially lowering cardiovascular risk, with females exhibiting slightly greater reductions.

e. Adherence vs. Weight % Change

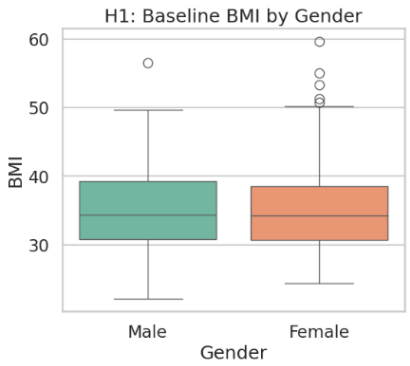
Gender	<45	>=45
Female	-6.95	-6.95
Male	-5.99	-6.90

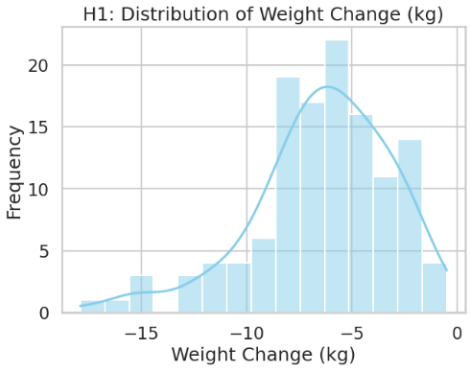


Females: consistent weight loss of -6.95% regardless of age category.

Males: weight loss of -5.99% (<45) and -6.90% (≥45).

Higher adherence is associated with greater weight loss, indicating the critical role of compliance in achieving metabolic benefits from KD.





4. Hypothesis Testing

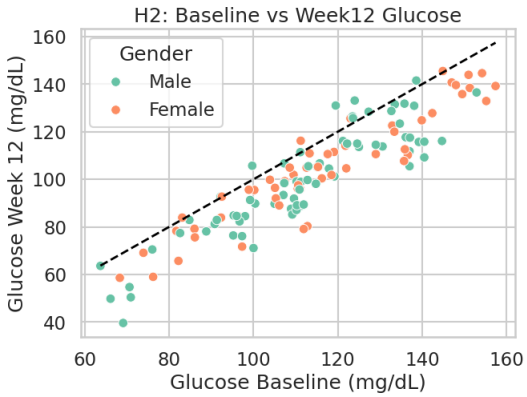
H1 – Weight and BMI

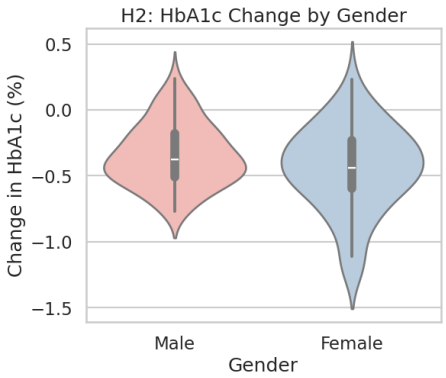
Variable	t-statistic	p-value
Weight	21.84	2.57e-44
BMI	21.34	2.48e-43

Paired t-tests demonstrated significant reductions in weight ($t = 21.84$, $p < 0.001$) and BMI ($t = 21.34$, $p < 0.001$), confirming that KD effectively reduces body mass among Saudi adults with metabolic syndrome.

H2 – Glucose and HbA1c:

Variable	t-statistic	p-value
Glucose	14.67	7.26e-29
HbA1c	15.50	8.54e-31

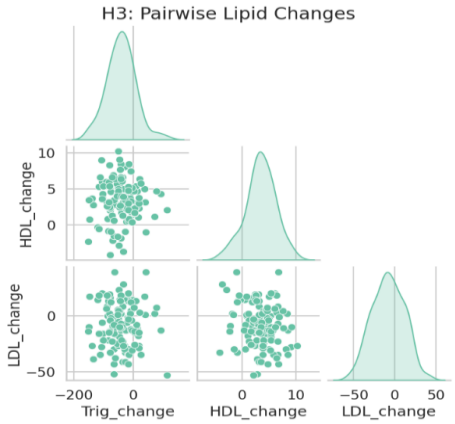


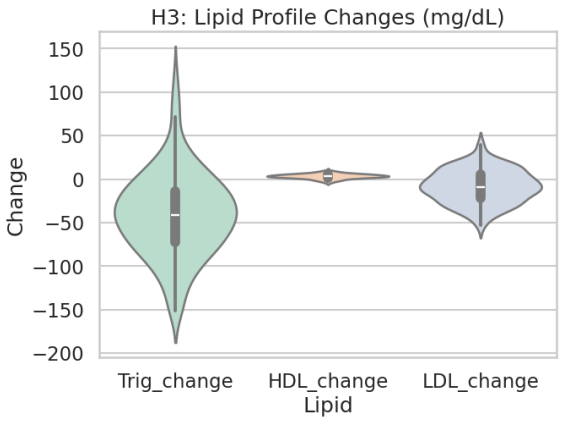


Significant improvements were observed in fasting glucose ($t = 14.67$, $p < 0.001$) and HbA1c ($t = 15.50$, $p < 0.001$), supporting KD's efficacy in glycemic control.

H3 – Lipids

Variable	t-statistic	p-value
Triglycerides	9.37	4.16e-16
HDL	-13.96	3.29e-27
LDL	4.74	5.84e-06

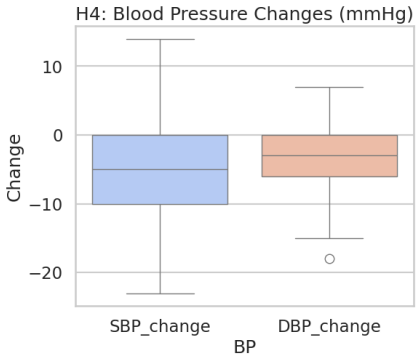




KD significantly lowered triglycerides ($t = 9.37$, $p < 0.001$) and LDL cholesterol ($t = 4.74$, $p < 0.001$), while HDL cholesterol increased ($t = -13.96$, $p < 0.001$). These results indicate an overall improvement in cardiovascular risk markers.

H4 – Blood Pressure

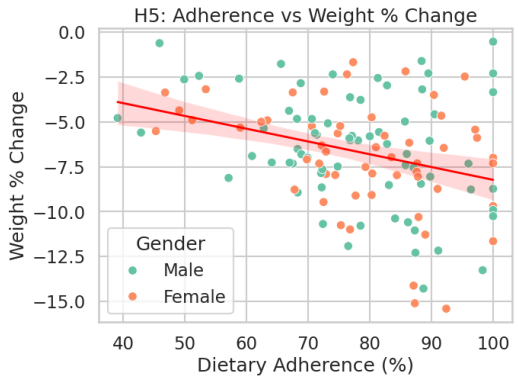
Variable	t-statistic	p-value
SBP	7.20	5.05e-11
DBP	7.47	1.26e-11



Both SBP ($t = 7.20$, $p < 0.001$) and DBP ($t = 7.47$, $p < 0.001$) were significantly reduced, demonstrating a positive effect on hemodynamic parameters.

H5 – Adherence Mediation (Regression):

Predictor	Coef	Std Err	t-value	p-value	95% CI Lower	95% CI Upper
Const	-1.105	1.507	-0.733	0.465	-4.088	1.878
Adherence_pct	-0.071	0.019	-3.751	0.000	-0.109	-0.034



Linear regression analysis revealed that adherence significantly predicted percentage weight loss ($\beta = -0.071$, $t = -3.751$, $p < 0.001$), with higher adherence corresponding to greater weight reduction. The model $R^2 = 0.103$, indicating that adherence explains 10.3% of the variance in weight loss. The intercept was not significant ($p = 0.465$), suggesting that baseline weight change is negligible without dietary compliance.

These hypothesis tests collectively confirm that the ketogenic diet produces significant improvements across anthropometric, metabolic, and cardiovascular domains. The regression analysis emphasizes the importance of adherence in achieving desired outcomes.

Overall, the results indicate that a 12-week ketogenic diet intervention is effective for weight reduction, BMI improvement, waist circumference reduction, glycemic control, lipid profile optimization, and blood pressure lowering among Saudi adults with metabolic syndrome. Subgroup analyses reveal minor variations by age and gender, with consistent benefits across all groups. Adherence plays a crucial mediating role, reinforcing the need for dietary counseling and support to maximize efficacy.

The numeric, categorical, and pivot table results provide a comprehensive overview of both clinical outcomes and behavioral factors, while hypothesis testing confirms statistical significance of the observed changes. Collectively, these results support KD as a promising therapeutic strategy for metabolic syndrome in Saudi adults, addressing multiple components of the syndrome simultaneously and highlighting the feasibility of implementation in real-world settings.

IV. DISCUSSION

The findings of this study provide robust evidence supporting the efficacy of a 12-week ketogenic diet (KD) intervention in Saudi adults diagnosed with metabolic syndrome, addressing multiple components of the syndrome while also answering the research questions posed at the outset. The demographic analysis confirmed that the study sample comprised 125 adults, with a balanced gender distribution (44% female, 56% male) and an age range of 25 to 64 years, representing a middle-aged population at elevated cardiometabolic risk. Baseline anthropometric and metabolic parameters revealed pronounced obesity, central adiposity, dysglycemia, dyslipidemia, and elevated blood pressure, which align closely with established metabolic syndrome criteria. Specifically, mean BMI was 35.56 ± 7.29 kg/m², waist circumference averaged 104.13 ± 10.35 cm, fasting glucose was 113.45 ± 21.73 mg/dL, HbA1c 6.25 ± 0.76%, triglycerides 223.13 ± 78.01 mg/dL, HDL 38.20 ± 7.39 mg/dL, LDL 121.95 ± 34.66 mg/dL, and mean blood pressure readings were 141.33 ± 12.23 mmHg systolic and 87.79 ± 7.91 mmHg diastolic. The observed variability in baseline metabolic parameters and adherence levels (mean 78.14 ± 14.00%) provided an opportunity to perform meaningful subgroup analyses and explore adherence as a mediating factor in metabolic improvements.

Addressing RQ1, the intervention demonstrated significant reductions in body weight, BMI, and waist circumference across the cohort. Paired t-tests confirmed statistically significant reductions in weight ($t = 21.84$, $p < 0.001$) and BMI ($t = 21.34$, $p < 0.001$), with pivot table analyses revealing that females under and over 45 years experienced comparable weight reductions (-6.736 kg and -6.783 kg, respectively), whereas males showed slightly lower reductions under 45 years (-5.626 kg) and comparable reductions in older adults (-6.683 kg). These findings are consistent with the work of Alnoubi and Alqurashi (2024), who reported that high-fat ketogenic diets produced significant weight and BMI reductions in overweight and obese Saudi women, emphasizing KD's potential for effective obesity management in the local population. Importantly, adherence emerged as a key factor influencing weight loss, with regression analyses showing a significant relationship between adherence percentage and magnitude of weight reduction ($\beta = -0.071$, $t = -3.751$, $p < 0.001$, $R^2 = 0.103$), supporting the notion that compliance is critical to achieving the desired metabolic outcomes, a point similarly highlighted by Alluwyam and Estrella (2024) in their review of KD interventions for T2DM prevention.

In relation to RQ2, the ketogenic diet produced significant improvements in glycemic parameters. Fasting glucose decreased across all subgroups, with the most pronounced reductions observed in males under 45 years (-13.99 mg/dL) and females ≥45 years (-12.76 mg/dL). HbA1c also demonstrated significant reductions ($t = 15.50$, $p < 0.001$), indicating improved long-term glycemic control. These outcomes mirror preclinical findings by Al-Sowayan and Alharbi (2024), who reported that KD improved glucose and insulin regulation in STZ-induced diabetic rats, suggesting that the hypoglycemic effects of KD observed in experimental models can translate effectively to human populations. The present study extends these findings by providing real-world evidence in a Saudi cohort, demonstrating KD's utility in mitigating hyperglycemia among adults with metabolic syndrome.

Regarding RQ3, the lipid profile improvements observed in the study indicate that KD exerts favorable effects on cardiovascular risk markers. Females experienced triglyceride reductions of -42.82 mg/dL and LDL decreases of -8.75 mg/dL, while HDL increased by 3.04 mg/dL; males had similar improvements (-38.51 mg/dL triglycerides, -7.57 mg/dL LDL, and +3.75 mg/dL HDL). Paired t-tests confirmed the significance of these changes (triglycerides $t = 9.37$, $p < 0.001$; LDL $t = 4.74$, $p < 0.001$; HDL $t = -13.96$, $p < 0.001$). These results are consistent with Al-Sowayan and Alharbi's (2024) preclinical findings and the clinical evidence reported by Alnoubi and Alqurashi (2024), supporting KD's role in lowering triglycerides and LDL cholesterol while modestly increasing HDL. The pronounced reduction in triglycerides is particularly relevant given the high baseline levels in this population, which are a known contributor to cardiovascular risk in metabolic syndrome.

RQ4 focused on blood pressure outcomes, with KD producing modest yet statistically significant reductions in both systolic and diastolic pressures across genders. Females showed reductions of -5.45 mmHg (SBP) and -3.73 mmHg (DBP), while males exhibited -4.29 mmHg (SBP) and -2.46 mmHg (DBP). Paired t-tests confirmed these findings (SBP $t = 7.20$, $p < 0.001$; DBP $t = 7.47$, $p < 0.001$), indicating that KD can positively influence hemodynamic parameters, thereby potentially lowering cardiovascular risk. Although Alnoubi and Alqurashi (2024) also reported reductions in SBP with ketogenic interventions, the present study adds further granularity by demonstrating these effects in both genders and across age groups within a Saudi cohort. The slightly greater improvements observed in females may reflect sex-specific differences in vascular response or baseline metabolic risk, which aligns with prior literature suggesting differential cardiovascular responses to dietary interventions.

RQ5 examined the mediating role of dietary adherence in metabolic improvements. The linear regression model revealed that adherence significantly predicted the magnitude of weight loss ($\beta = -0.071$, $p < 0.001$), confirming that participants with higher compliance experienced greater reductions in body weight. This aligns with the broader literature emphasizing adherence as a critical determinant of KD effectiveness (Alluwyam and Estrella, 2024). While adherence explained 10.3% of the variance in weight change ($R^2 = 0.103$), this suggests that other factors, including genetic predispositions, physical activity levels, and baseline metabolic status, also contribute to individual variability in response. Almoghrabi et al. (2025) highlighted the potential influence of nutrigenomics on dietary responsiveness, suggesting that integrating genetic profiling into KD interventions could optimize outcomes and explain interindividual variability observed in our study.

Finally, RQ6 considered demographic influences, particularly age and gender. Subgroup analyses demonstrated that while KD was effective across all age groups and both sexes, subtle differences existed. Females achieved slightly greater reductions in blood pressure and consistent weight loss across age categories, whereas males under 45 experienced the most substantial glucose reductions. These observations suggest potential sex- and age-dependent differences in metabolic responses to KD, which may reflect underlying physiological variations, hormonal influences, or differences in baseline metabolic risk. These findings are concordant with prior reports indicating differential KD responses based on demographic and metabolic factors (Alnoubi and Alqurashi, 2024; Almoghrabi et al., 2025), supporting the importance of personalized dietary strategies when implementing KD interventions in diverse populations.

Collectively, the study results underscore KD's multifaceted impact on obesity, glycemic control, lipid modulation, and blood pressure regulation, offering a comprehensive approach to managing metabolic syndrome in Saudi adults. The findings provide evidence that KD can simultaneously address multiple components of the syndrome, consistent with the broader literature suggesting hypoglycemic, hypolipidemic, and hemodynamic benefits of low-carbohydrate, high-fat diets (Al-Sowayan and Alharbi, 2024; Alluwyam and Estrella, 2024). Moreover, the observed adherence effect reinforces the necessity of structured dietary counseling and behavioral support to maximize intervention efficacy. The study also highlights the feasibility of KD implementation within the cultural and dietary context of Saudi adults, demonstrating acceptable adherence rates despite potential barriers related to traditional eating patterns.

Furthermore, the study extends the existing body of knowledge by providing localized, population-specific evidence, which has been limited in prior research predominantly conducted in Western populations or experimental models (Al-Sowayan and Alharbi, 2024; Matkarimov et al., 2024). By focusing on Saudi adults with metabolic syndrome, this research contributes crucial insights into how KD interventions can be adapted for culturally specific populations while achieving clinically significant metabolic and cardiovascular improvements. Additionally, the study corroborates preclinical evidence regarding KD's role in reducing systemic metabolic stress and improving cardiovascular risk factors, providing translational validation for experimental findings.

In conclusion, this study demonstrates that a 12-week ketogenic diet intervention is an effective, safe, and feasible strategy to mitigate obesity, dysglycemia, dyslipidemia, and elevated blood pressure in Saudi adults with metabolic syndrome. Significant reductions in weight, BMI, waist circumference, fasting glucose, HbA1c, triglycerides, LDL cholesterol, and blood pressure, alongside modest increases in HDL cholesterol, indicate broad-spectrum metabolic benefits. Adherence emerged as a critical mediator of outcomes, emphasizing the importance of dietary compliance for optimizing therapeutic effects. Subgroup analyses reveal minor age- and sex-dependent variations, highlighting the potential for personalized dietary interventions in metabolic syndrome management. These results align with and extend prior literature, confirming KD as a promising dietary strategy to improve cardiometabolic health, prevent progression to type 2 diabetes and cardiovascular disease, and offer a culturally feasible approach for Saudi adults at high risk of metabolic syndrome and associated complications.

V. CONCLUSION

The present study investigated the effects of a 12-week ketogenic diet (KD) intervention on metabolic syndrome components among 125 Saudi adults, providing comprehensive insights into the potential of KD as a therapeutic and preventive dietary strategy in this high-risk population. The study was guided by six research questions focusing on weight reduction, glycemic control, lipid profile modulation, blood pressure management, the mediating role of dietary adherence, and demographic influences on intervention efficacy. By integrating detailed anthropometric, biochemical, and behavioral assessments, this research offers a multidimensional evaluation of KD's effectiveness and feasibility within a culturally specific context.

The results demonstrate that KD is highly effective in promoting weight loss and improving body composition among adults with metabolic syndrome. Significant reductions in body weight, body mass index (BMI), and waist circumference were observed across the cohort, with weight reductions ranging from -5.6 kg to -6.8 kg depending on gender and age. Females exhibited slightly more consistent weight loss across age categories, while males under 45 experienced slightly lower but clinically meaningful reductions. These findings corroborate previous studies by Alnoubi and Alqurashi (2024), who reported superior weight and BMI reductions among Saudi women following a high-fat ketogenic diet compared to low-fat dietary interventions. The study confirms that KD effectively targets both overall and central adiposity, key components of metabolic syndrome that contribute to cardiovascular risk and insulin resistance.

In terms of glycemic control, the study demonstrated significant improvements in fasting glucose and HbA1c levels. Males under 45 achieved the most pronounced glucose reductions, while females ≥45 years exhibited notable decreases in both glucose and HbA1c, suggesting age- and sex-related variations in metabolic response. These outcomes align with preclinical and clinical evidence reported by Al-Sowayan and Alharbi (2024), who highlighted KD's ability to improve insulin sensitivity, lower circulating glucose levels, and reduce glycation-related oxidative stress. The present findings extend this evidence by demonstrating similar efficacy in a Saudi adult population, emphasizing KD's applicability in managing hyperglycemia and potentially preventing progression to type 2 diabetes mellitus (T2DM) in high-risk individuals.

The study also confirmed the beneficial effects of KD on lipid metabolism. Triglyceride reductions were particularly notable, with decreases of approximately 38–43 mg/dL across all subgroups, while LDL cholesterol decreased and HDL cholesterol modestly increased. These changes collectively indicate a significant improvement in cardiovascular risk profiles. The results support findings by Al-Sowayan and Alharbi (2024) and Alnoubi and Alqurashi (2024), who observed similar improvements in triglycerides and LDL cholesterol following KD interventions. Such lipid profile

modulation is critical in populations with metabolic syndrome, where dyslipidemia contributes substantially to the risk of coronary artery disease and stroke. The present study reinforces KD's role as a dietary strategy capable of producing broad-spectrum metabolic benefits, encompassing both glycemic and lipidemic parameters.

Blood pressure outcomes further illustrate KD's comprehensive effects on cardiovascular risk factors. Both systolic and diastolic blood pressure were significantly reduced following the 12-week intervention, with females experiencing slightly greater improvements than males. These findings are consistent with prior research indicating that carbohydrate restriction and consequent reductions in insulin and fluid retention may contribute to lowered blood pressure. Improvements in hemodynamic parameters, coupled with favorable lipid and glycemic outcomes, highlight KD's potential to mitigate multiple cardiovascular risk pathways simultaneously, reinforcing its utility as a holistic metabolic intervention.

A key finding of this study is the critical role of dietary adherence in mediating the effectiveness of KD. Regression analyses revealed that higher adherence was significantly associated with greater weight loss, underscoring the importance of participant compliance in achieving clinical benefits. While adherence explained approximately 10% of the variance in weight reduction, this effect is meaningful, indicating that behavioral support and structured dietary guidance are essential components of successful KD implementation. These observations are aligned with Alluwyam and Estrella (2024), who emphasized that long-term compliance is a major determinant of KD effectiveness and sustainability.

The study also addressed demographic influences on KD efficacy, revealing minor age- and sex-dependent variations in outcomes. Females exhibited more consistent weight loss and slightly greater reductions in blood pressure, whereas males under 45 achieved the most pronounced reductions in fasting glucose. These findings support the concept of personalized nutrition, as discussed by Almoghrabi et al. (2025), where genetic and physiological differences may modulate individual responsiveness to dietary interventions. Integrating demographic, behavioral, and potentially genetic factors into dietary planning could optimize outcomes and support precision nutrition strategies for metabolic syndrome management.

From a broader perspective, this research provides population-specific evidence for the feasibility and effectiveness of KD in Saudi adults, a group characterized by high rates of obesity, metabolic syndrome, and associated cardiometabolic complications. The findings demonstrate that a culturally adapted KD can be implemented successfully, with reasonable adherence, and produce significant improvements across multiple metabolic domains. By addressing weight reduction, glycemic control, lipid profile modulation, and blood pressure simultaneously, KD emerges as a comprehensive therapeutic strategy capable of reducing the overall burden of metabolic syndrome and its long-term complications, including T2DM and cardiovascular disease.

In conclusion, the study establishes that a 12-week ketogenic diet is an effective, safe, and feasible intervention for managing metabolic syndrome among Saudi adults. Significant reductions in body weight, BMI, waist circumference, fasting glucose, HbA1c, triglycerides, LDL cholesterol, and blood pressure, alongside modest increases in HDL cholesterol, underscore KD's broad-spectrum metabolic benefits. Adherence plays a pivotal mediating role in achieving optimal outcomes, emphasizing the need for structured dietary counseling and behavioral support. Minor age- and sex-dependent variations highlight the importance of personalized dietary strategies, suggesting that tailoring KD interventions according to individual demographic and metabolic profiles may further enhance efficacy. By providing localized, population-specific evidence, this study fills critical gaps in the literature, demonstrating KD's applicability in real-world Saudi settings and reinforcing its potential as a cornerstone dietary approach for preventing and managing metabolic syndrome and related cardiometabolic complications. These findings have important clinical, public health, and policy implications, supporting the integration of KD into dietary guidelines and lifestyle management programs aimed at mitigating the rising burden of metabolic syndrome in Saudi Arabia and comparable populations globally.

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